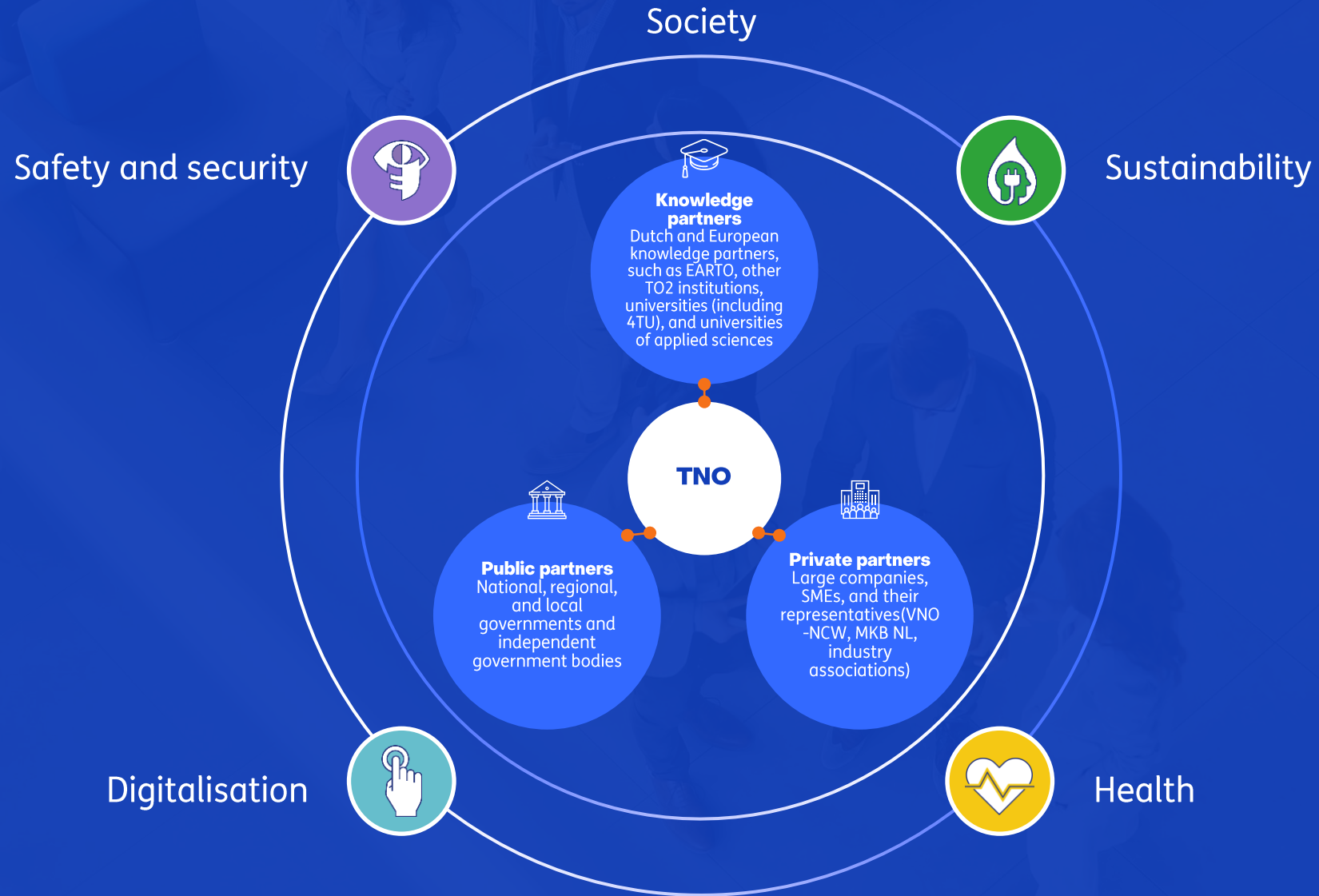


CO₂ Capture, Use & Storage: Innovative Solutions

NAP Contact Meeting

Jurriaan Boon | Zeist





Energy & Materials Transition

The energy and materials transitions are inextricably linked in efforts to achieve the 2050 climate goals.

TNO Energy & Materials Transition connects these transitions through applied research, knowledge, and expertise relating to technologies, circularity, business models, and legislation and regulations. This is how we come up with customised advice and solutions.



CO₂ Neutral Industry

- **Industrial Carbon Capture**
 - In-process capture (SEWGS), end-of-pipe capture
- **Sustainable Industrial Heat System**
 - Heat pumps, heat efficiency, combustion, CO₂ neutral heating
- **Energy Infrastructure for Industry**
 - Gas/liquid infra & storage, ad-mixing, safety of infra, North Sea Energy
- **Clean Hydrogen Production**
 - Electrolyser development, methane pyrolysis
- **Biobased Fuels & Chemicals**
 - Gasification, sugar/lignin, seaweed, biochar, aromatics, biorefinery
- **Synthetic Fuels & Chemicals**
 - Synthetic aviation and heavy transport fuels, MeOH, DME, ethylene



Europe

- Emissions Trading System ETS
 - 2030 ETS target -62% (was: -43%) relative to 2005
 - Phase out free allocations by 2034
- Renewable Energy Directive RED
 - 42.5% renewable energy by 2030
 - Labelling method for industrial products made with renewable energy
 - Target for renewable energy in industry: +1.6%/y
- Carbon Border Adjustment Mechanism CBAM
 - Carbon tariff on imports (2026): cement, iron & steel, aluminium, fertilisers, electricity
- Green Deal Industrial Plan
 - Net-Zero Industry Act: Expedited permitting, skills development, IPCEI
 - Critical Raw Materials Act
 - RepowerEU

The Netherlands

Klimaatwet

- Industry climate neutral 2050
- 2023-2030
 - Industry 29,6 Mton CO₂ emissions in 2030 (-66% compared to 1990)
 - Contribute to -50% raw materials
- 2030-2050
 - Towards 100% circulair and climate neutral sector

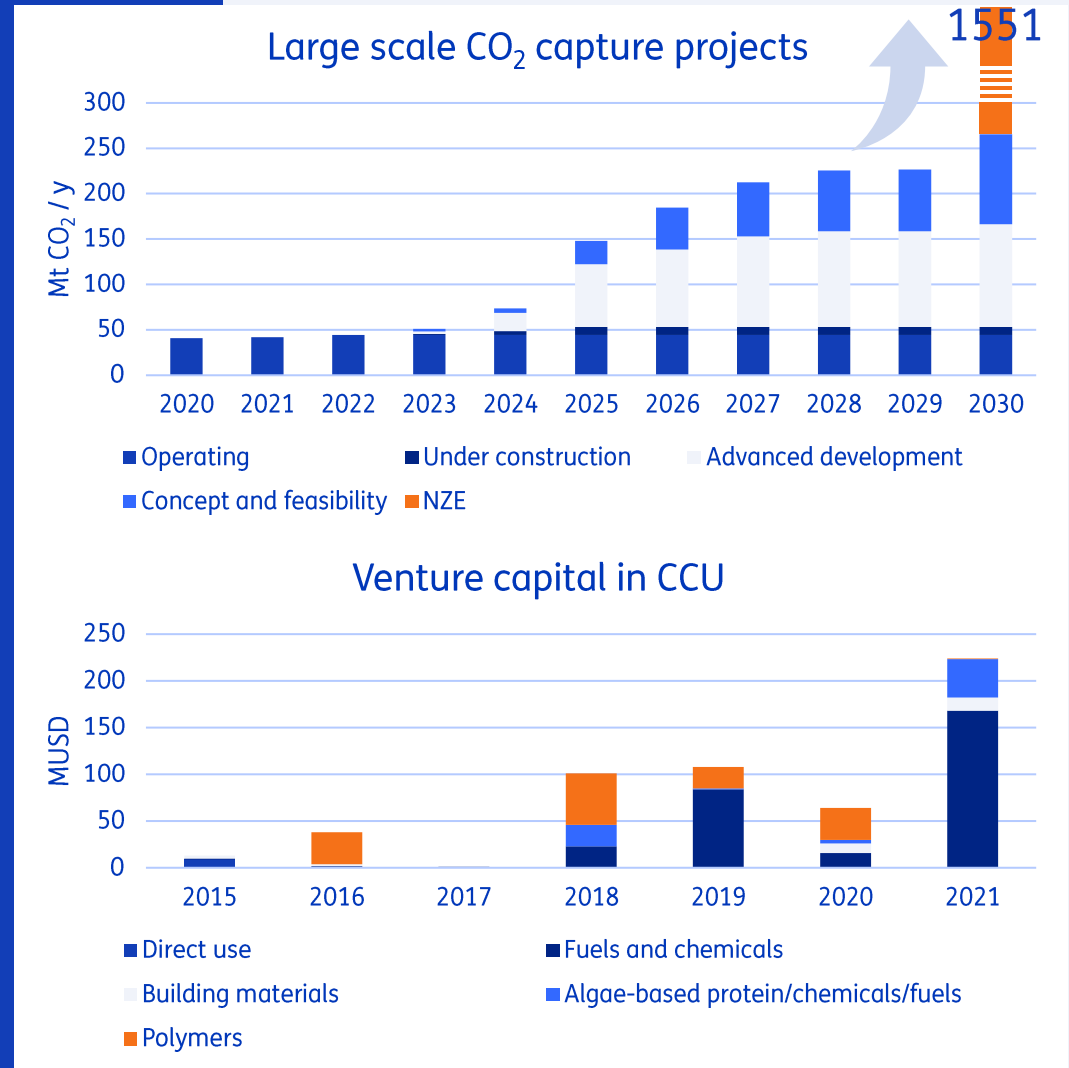
Circular carbon

CCUS facilities currently capture ~45 Mt CO₂ globally

- NZE: This needs to increase dramatically!

CO₂ use can bring important climate benefits, but ...

- CO₂ use does not equal emissions reduction
- Climate benefits depend on several factors
 - CO₂ source
 - Displaced function (incl retention, scale)
 - Carbon intensity of the conversion process



CO₂ Capture, Use & Storage: Innovative Solutions



- Process intensification
- **SEWGS** for CO₂ capture
- **SEDMES** for CO₂ conversion

Process Intensification: Beyond unit operations

- Henri van 't Hoff & Henry le Chatelier (1884):
... changes in the temperature, pressure, volume, or concentration of a system will result in predictable and opposing changes in the system in order to achieve a new equilibrium state.

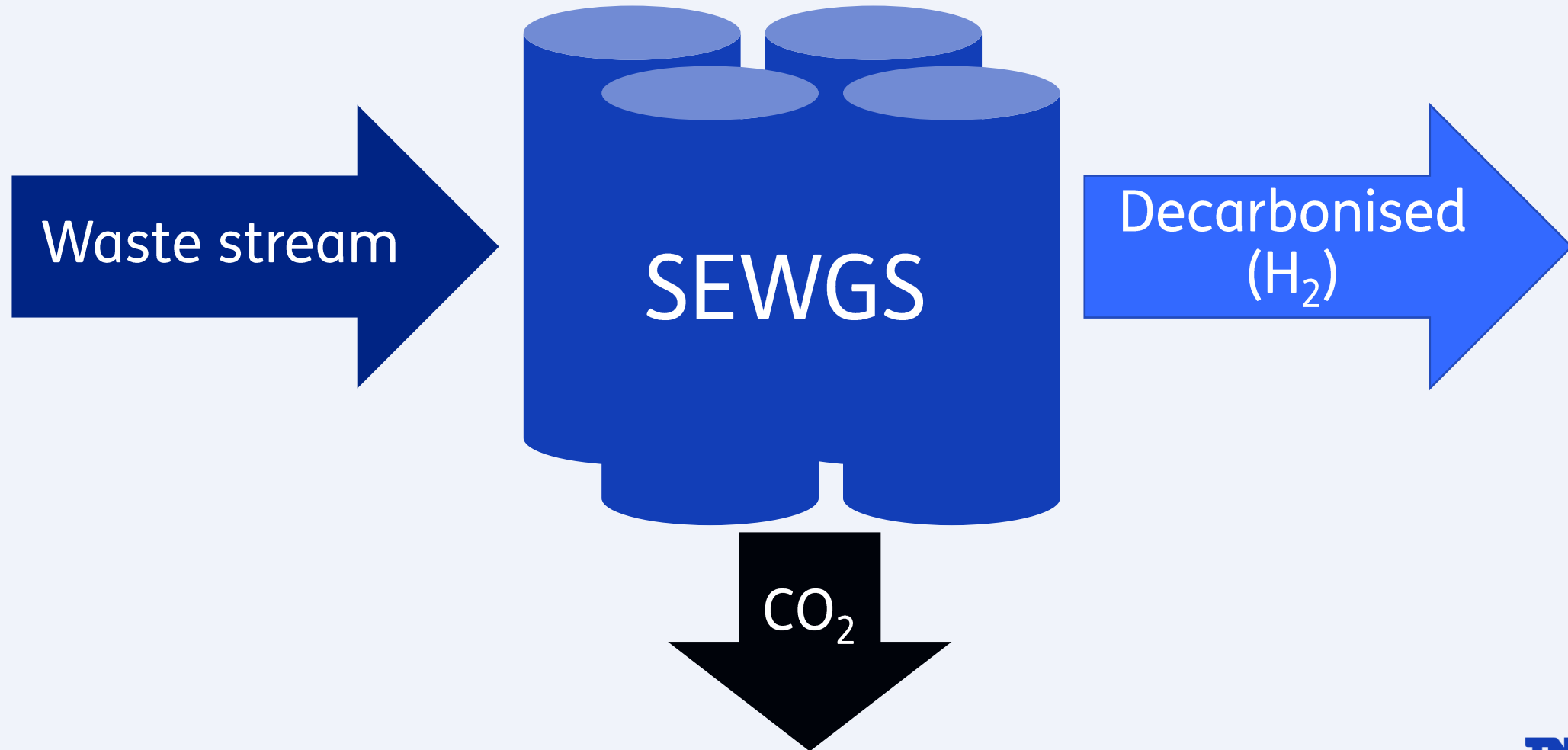


Removal of *D* from the reaction mixture
(Adsorption, membrane, etc.)

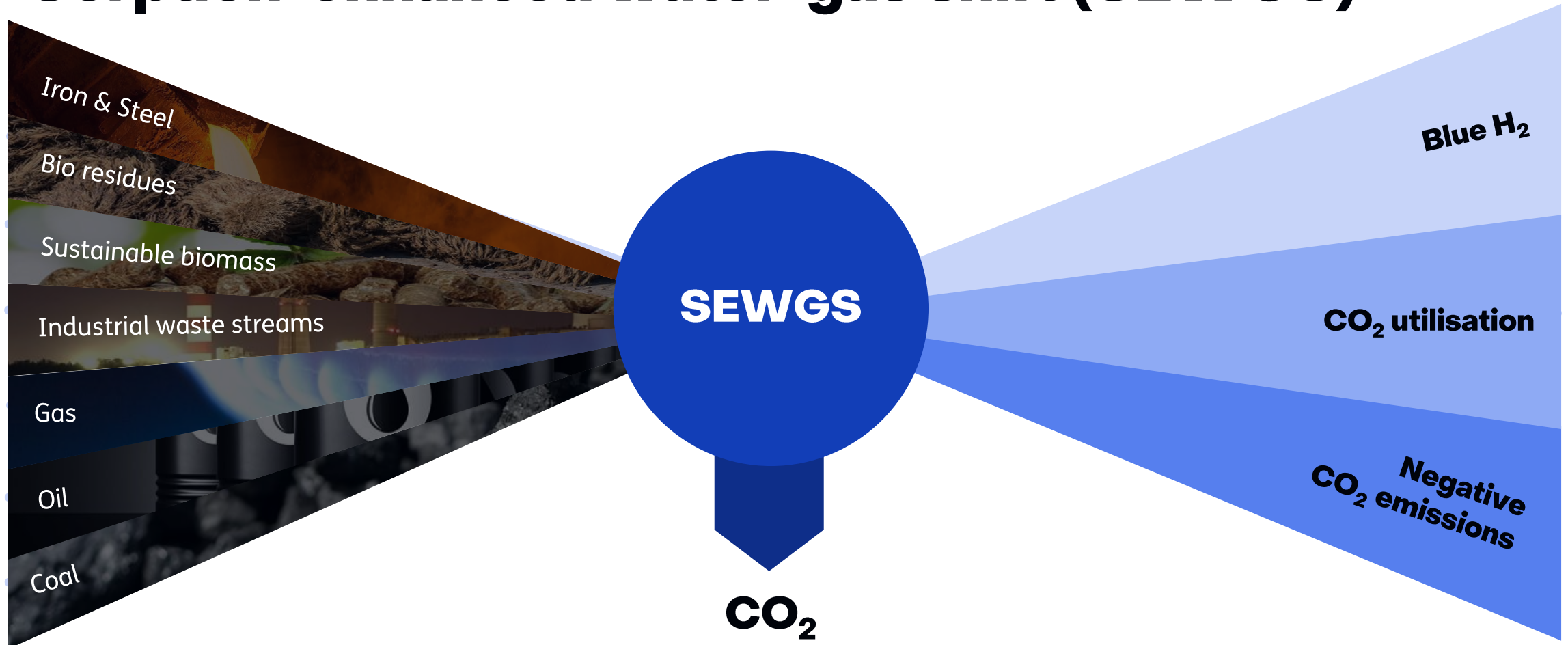


SEWGS

- Sorption-enhanced water-gas shift



Sorption-enhanced water-gas shift (SEWGS)



STEPWISE project

2 Campaigns
**> 5000
cycles**



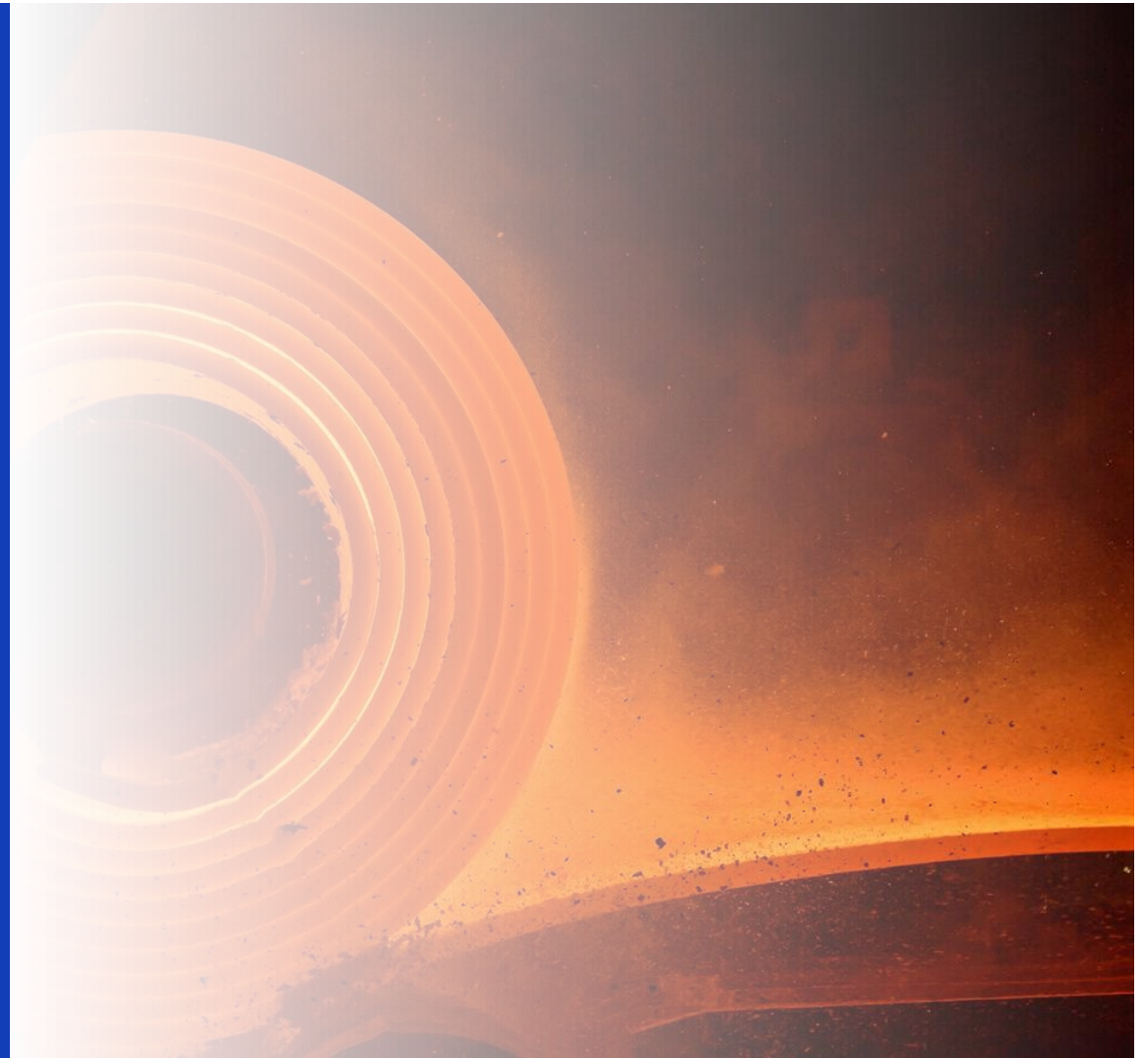
CO₂ purity up to
95%



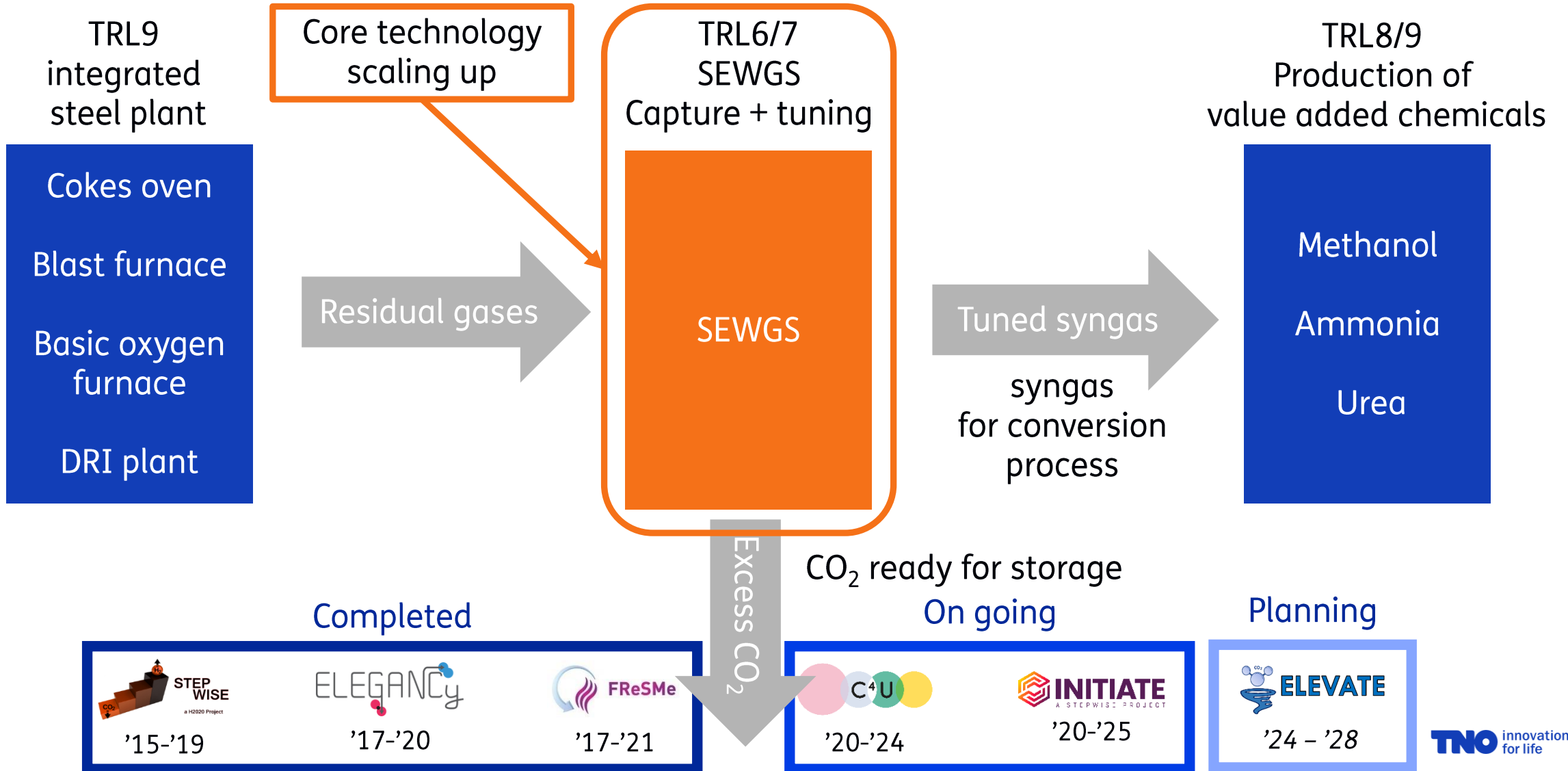
Carbon Capture rate up
to
100%



Cost reduction
compared to state of
the art
28%



Overview & Background





Status

Results TRL6 (FReSMe)

- 25 ton Methanol produced at TRL6
- Methanol utilised in the Stena Germanica
- Integrity of functional materials integrity
- Stable performance for Blast Furnace Gas for >10 000 cycles

Ongoing TRL7 (INITIATE)

- 3 ton of NH₃ installation
- Multicolumn capture equipment
- Positive business case even without regulations
- Basic Oxygen Furnace Gas to be used



Demonstrate NH_3 from BOFG at TRL-7

Gas pipeline



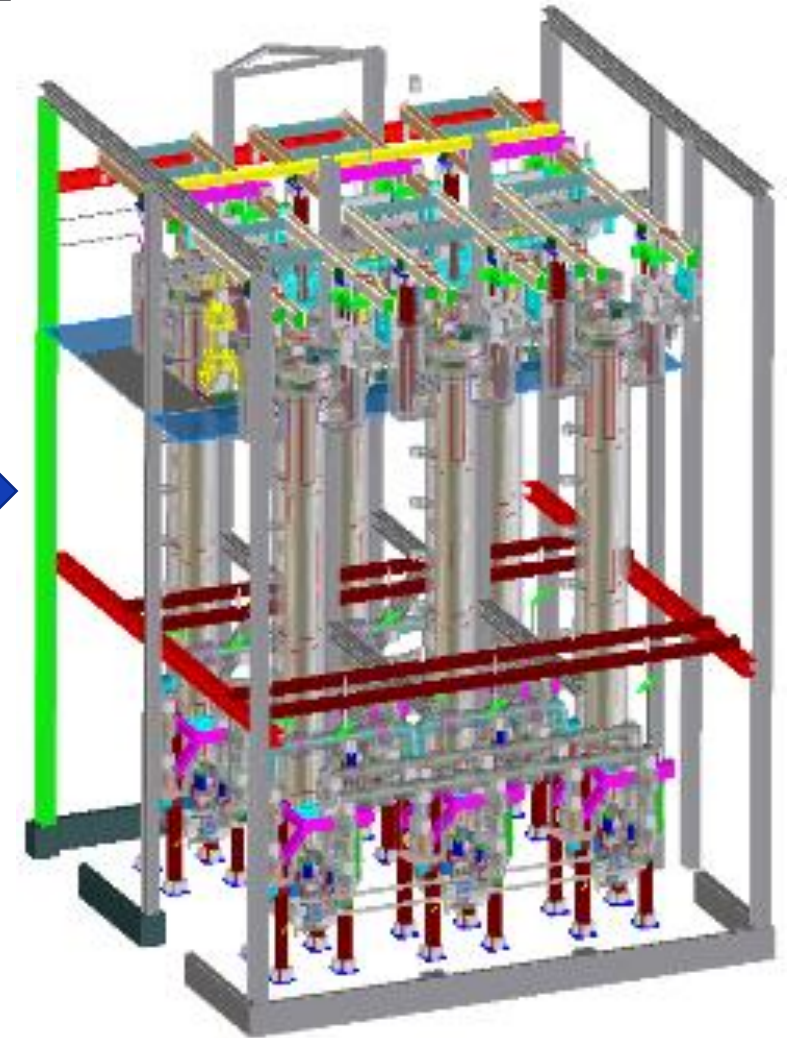
Compressor



Pre-Shift



SEWGS – Single Column



Towards commercial deployment

Current
TRL8 phase
TRL9 phase

Capture de-risking
for CO₂ Storage

Added value route

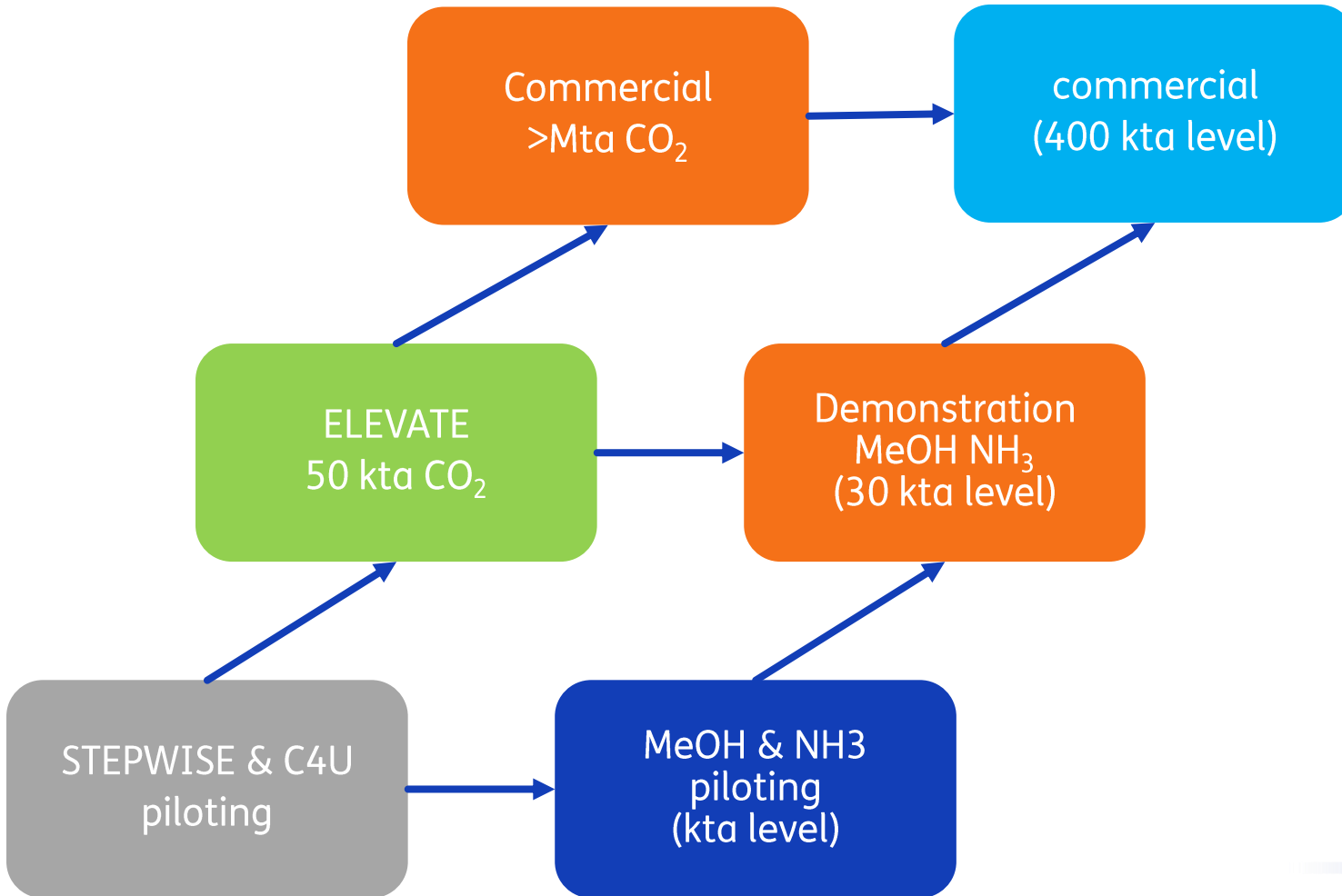
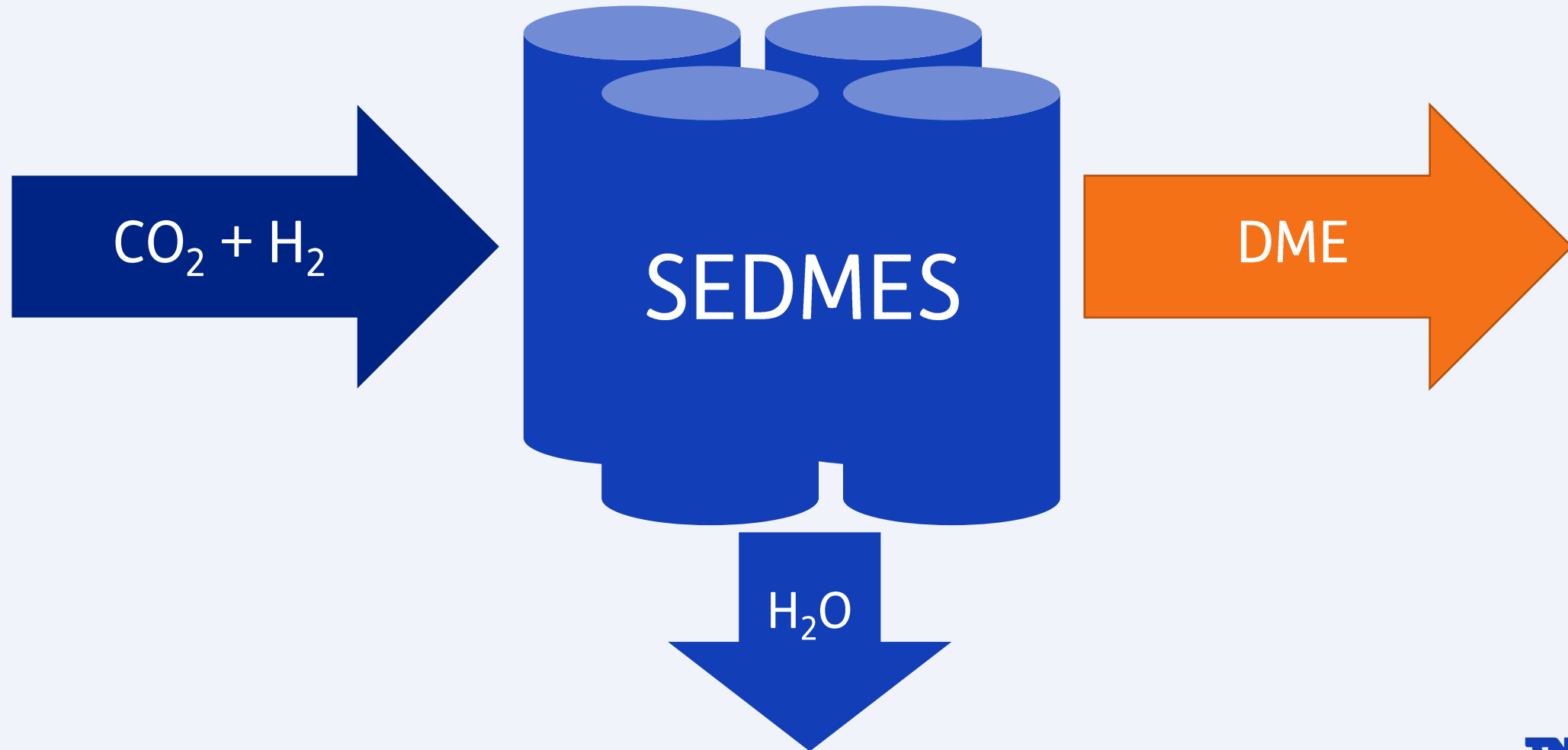


Photo by [Florian Weichert](#) on [Unsplash](#)

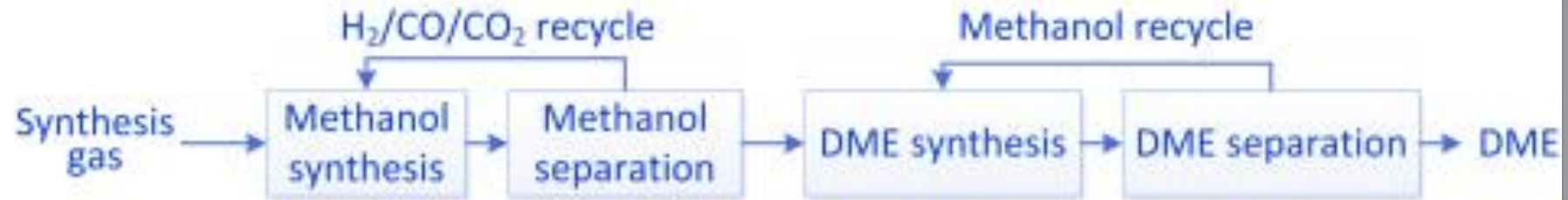
SEDMES

- Sorption-enhanced DME synthesis

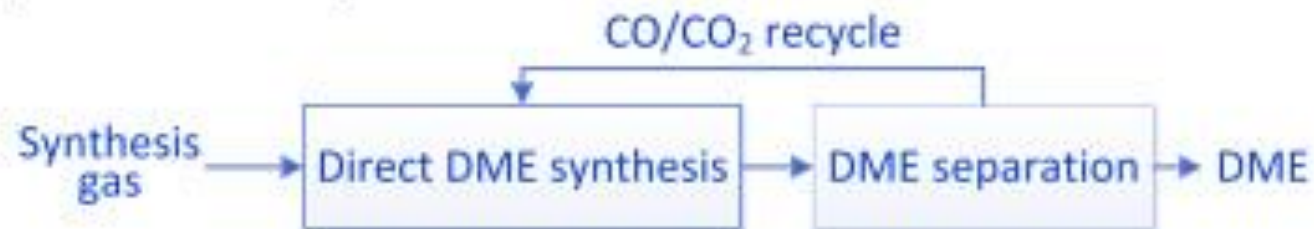


SEDMES

a) Conventional DME production



b) Direct DME production




c) Sorption-enhanced DME production (SEDMES)



SEDMES


• Why DME?

Industry




- Industrial high-temperature heating is hard to electrify. **rDME can be used as a 100% renewable fuel in industrial applications.**
- Coal or oil-fired boilers could be replaced with DME boilers, as the use of these fuels is increasingly being phased out. **Existing LPG boilers could use a rDME/LPG blend, or be converted to run on 100% DME.**

Domestic heat and cooking




- rDME blended up to 20% with LPG can be used in existing domestic heating and cooking appliances.
- This is an immediately available solution to **reduce the GHG emissions from the domestic off-grid sector**, without the cost of installing new technologies

Transport



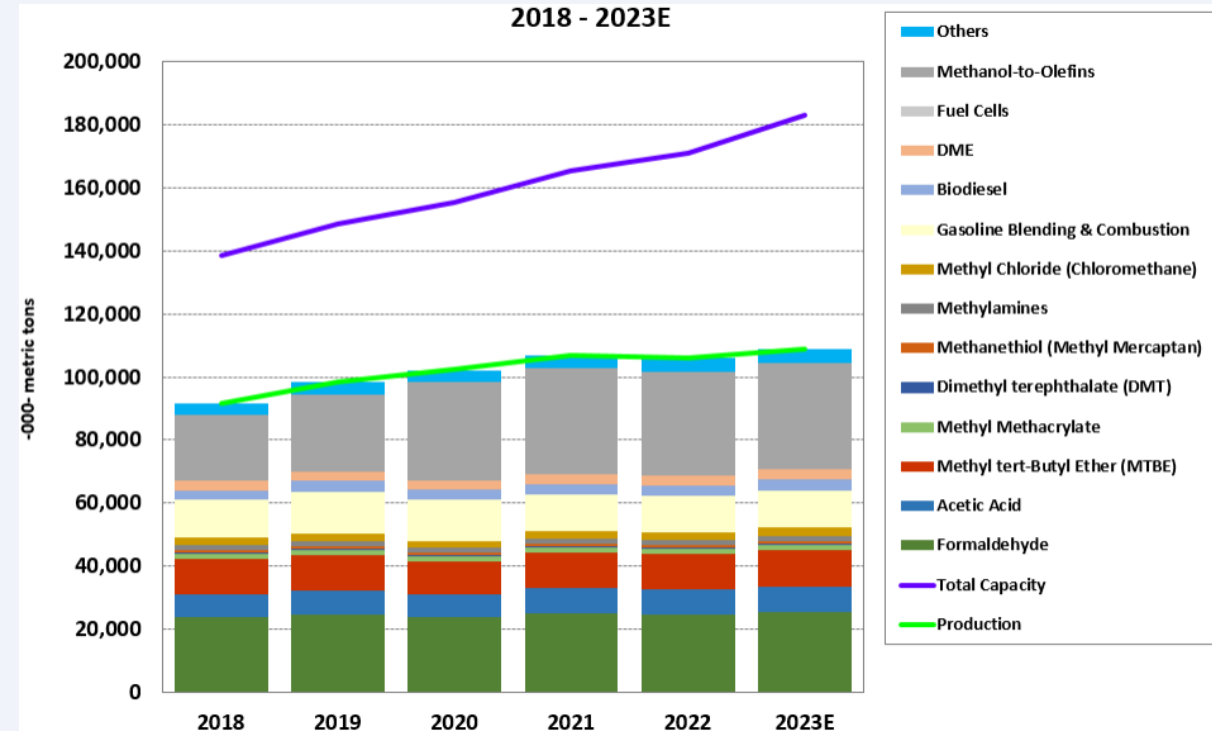
- rDME can be used as a **replacement for diesel in engines**, requiring only an inexpensive retrofit to the vehicle.
- This solution provides a **valuable renewable fuel option** for the hard-to-decarbonise heavy-duty transport sector.
- rDME can also be **blended at 20% into LPG for use** in existing LPG vehicles

Hydrogen carrier



- A litre of liquid DME contains **more hydrogen than a litre of liquid hydrogen**, so it could also be used as a hydrogen carrier
- A straightforward process **converts DME back into hydrogen** for use in industry, transport or domestic heating and cooking.

Methanol (DME)



SEDMES: Development and scale-up

2014 - 2017



SPIDER

25 g

2018



CATE

50 g

2019



SEWGS-1

2 kg

2020



SEWGS-7

30 kg



500 kg

Interreg 
 2 Seas Mers Zeeën
European Regional Development Fund



POWERED



Dutch consortium advances efficient CO₂ conversion technology for DME

Energy Transition Campus Amsterdam






Thank you for your attention

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